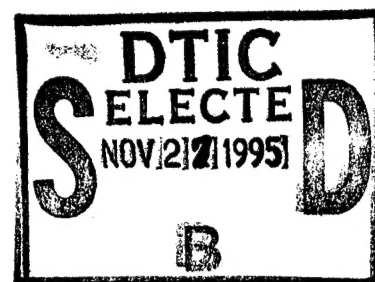


AMRL-TR-68-176



**MEASUREMENT AND ANALYSIS OF
BIOACOUSTIC ENVIRONMENTS ABOARD
AC-119G AND AC-130A GUNSHIPS**

JUSTUS F. ROSE, JR., MAJOR, USAF



SEPTEMBER 1969

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13. ABSTRACT

Acoustic noise measurements were made at crewmember locations on board an AC-119G and AC-130A gunship. Measurements were made during taxi, take-off, climb, and cruise power settings. In addition, measurements were taken during firing of the four 7.62 mm miniguns on the AC-119G and the four 7.62 mm miniguns and four 20mm vulcans on the AC-130A. Measurements were at typical crewmember locations throughout each aircraft during various weapon combination firing configurations. The data are presented in data zones and each zone is shown attenuated by each of four in-service ear protection devices. Specific ear protection recommendations are made for each aircraft for both ambient and gunfiring noise environments.

Security Classification

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Foreword

The measurement program and analysis reported herein was performed by the Biodynamics and Bionics Division, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. The program was conducted by Justus F. Rose Jr., Major, USAF, Biodynamics Environment Branch, under Project 7231, "Biomechanics of Aerospace Operations," and Task 723104, "Biodynamic Environment of Aerospace Flight Operations." Acknowledgment is made of the assistance of Dr. Charles W. Nixon and William C. Knobloch Jr., SSgt. USAF, of the Biological Acoustics Branch. The research was initiated September 1968 and completed November 1968.

This technical report has been reviewed and is approved.

C. H. KRATOCHVIL, Colonel, USAF, MC
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Section I

INTRODUCTION

This report presents the results of measurements and analyses of the acoustic noise produced on board the AC-119G and AC-130A gunships during taxi, take-off, climb, cruise, and gunfiring during cruise. These results describe the sound pressure level (SPL) spectra produced at typical crewmember locations during operation of these aircraft.

The data are plotted in data zones made up of data taken at particular operating conditions and/or particular locations in the aircraft for both ambient and gunfiring environments. Applicable damage risk criteria are applied to each data zone to determine if a potential unsafe condition exists with respect to noise-induced hearing loss. Each data zone is then attenuated by each of four in-service ear protection devices and again compared with the applicable damage risk criteria to determine if the particular device will provide adequate ear protection in the noise environment.

Specific ear protection recommendations are made for each aircraft for both the ambient and gunfiring noise environments.

Section II

MEASUREMENT PROGRAM

GENERAL

On 16 September 1968, sound pressure level measurements were made on board AC-119G, No. 53-8089 at Lockbourne AFB, Ohio. Sixteen data runs were accomplished; four runs during taxi, take-off and Maximum Except Take-Off (METO) climb, four runs during cruise with the Gas Turbine Power Unit (GTPU) operating, four runs during cruise power setting with the GTPU not operating, and four runs during gunfiring with the GTPU and illuminator operating. The AC-119G is equipped with two Wright R-3350-89B reciprocating engines, each with a four bladed Aero-products-Allison propeller, and the aircraft was configured internally as shown in figure 1.

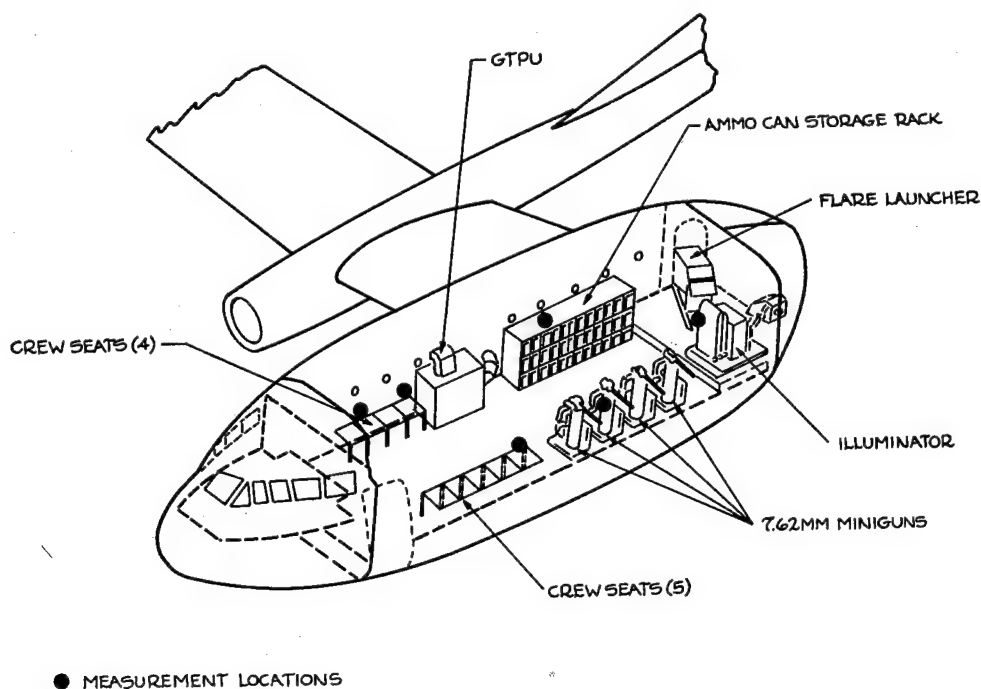


Figure 1. AC-119G Gunship General Arrangement and Measurement Locations

On 18 September 1968, sound pressure level measurements were made on board AC-130A, No. 54-1623 at Lockbourne AFB, Ohio. Three data runs were accomplished in the cargo compartment during taxi, take-off, and cruise. On 23 September 1968, measurements were taken on board AC-130A, No. 54-1625 at Eglin AFB, Florida. Twenty-two data runs were accomplished; twelve runs at ambient conditions at typical crewmember locations throughout the aircraft, four runs at the aft gunner's station during gunfiring, and six runs at the forward gunner's station and locations in the forward cargo compartment during gunfiring.

The AC-130A is equipped with four Allison T56-A-9 turboprop engines, each with a three bladed Aeroproducts propeller, and the aircraft was configured internally as shown in figure 2. AC-130A, No. 54-1625 did not have the ¼-inch nylon ballistic felt curtains installed around the weapons or in the aisle adjacent to the radar booth. Neither aircraft had the wind deflector installed on the leading edge of the scanner's hatch that will be on the production models of the AC-130A gunships.

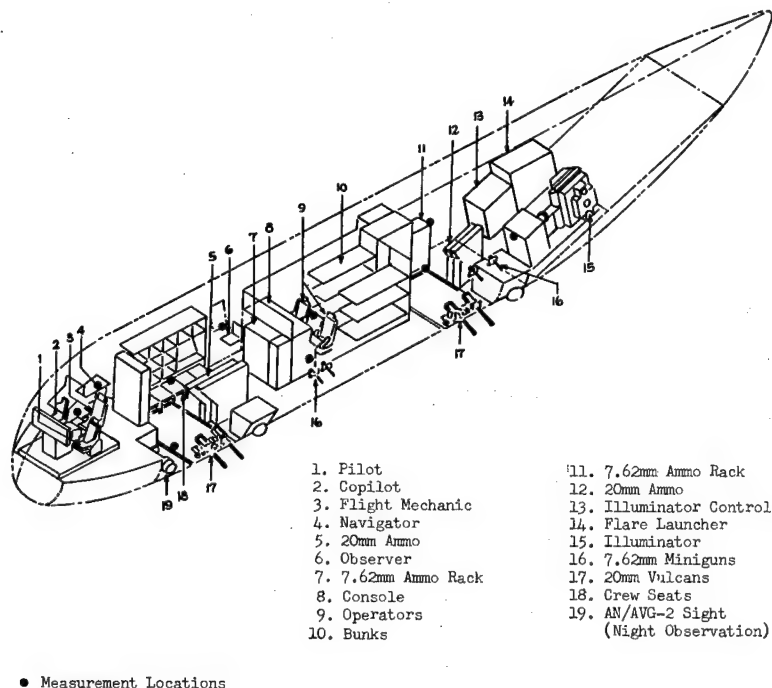


Figure 2. AC-130A Gunship General Arrangement and Measurement Locations

MEASUREMENT LOCATIONS

AC-119G

The ambient data runs were made in the cargo compartment where personnel are located during operation of the aircraft (figure 1). The measurements were made at locations that are not necessarily occupied for the full duration of the mission, but do provide accurate sound pressure levels that are present throughout the cargo compartment. The gunfiring data runs were made at locations where the gunners would typically be positioned during that portion of the mission when the guns are being used. SPL were measured during firing of the No. 1 minigun, No. 4 minigun, and with all four miniguns firing simultaneously. Measurements during gunfiring were taken only at positions in close proximity to the weapons because these positions will produce the highest SPL; adequate protective gear and procedures to protect the individuals at these positions will automatically protect them at other positions.

AC-130A

The twelve ambient data runs were made at typical crewmember stations where personnel might be located during operation of the aircraft (figure 2). The crewmember stations for the

evaluation were considered to be full 6-hour exposure locations while some of the measurement locations, such as the aisle adjacent to the radar operator's booth, the position adjacent to the rear door, and the forward compartment crew seats will not necessarily be occupied for the full duration of the mission. The gunfiring data runs were made at locations where the gunners would typically be positioned during the portion of the mission when the guns are being used. Sound pressure levels were measured in the forward and aft portions of the aircraft as well as in the aisle adjacent to the No. 1 and No. 2 miniguns during various mix configurations of weapons fire. The measurements in the forward gunner's station were taken during firing of the No. 1 and No. 2 miniguns and the No. 1 and No. 2 vulcans; and those at the aft gunner's station were taken during firing of the No. 3 and No. 4 miniguns and the No. 3 and No. 4 vulcans. Again, the highest SPL will be in close proximity to the weapons firing; and protective gear and procedures that will adequately protect the individuals at these positions will automatically protect them at other positions. The data run made during firing of all eight weapons was at the aisle position adjacent to the No. 1 and No. 2 miniguns because this position was thought to yield the highest noise levels due to the physical positioning of the eight weapons in the aircraft.

INSTRUMENTATION AND DATA REDUCTION

A portable, high quality instrumentation package (PORTAPAK) developed in this laboratory was used to acquire data. This system (figure 3) employs condenser microphones for acoustic transducers, signal conditioning equipment to provide maximum signal to noise and dynamic range, and a battery operated portable magnetic tape recorder. Specifications for this system are in brief: frequency response 20 Hz to 20 kHz (essentially flat throughout this frequency band), dynamic range with 1 inch condenser microphone 59 to 135 dB, dynamic range with $\frac{1}{2}$ inch condenser microphone 72 to 148 dB, gain control -15 to 30 dB. A battery operated pistonphone was used as a reference sound pressure level in the field of calibration.

Spectral analyses of the recorded data were accomplished in the laboratory using an analog processing system employing a spectrometer and graphic level recorder with true root mean square detection (figure 4).

The entire system was calibrated and small corrections were applied to the data to compensate for system response. Care was taken to insure at least a 10 dB signal to noise ratio at all times.

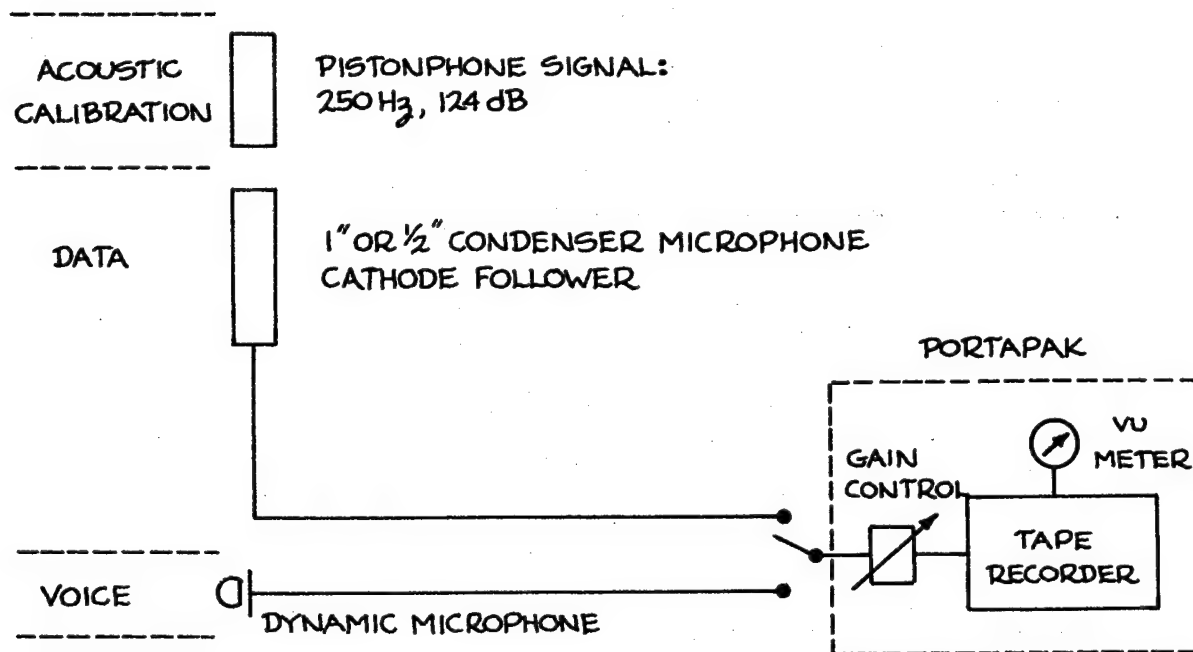


Figure 3. Portable Data Acquisition System

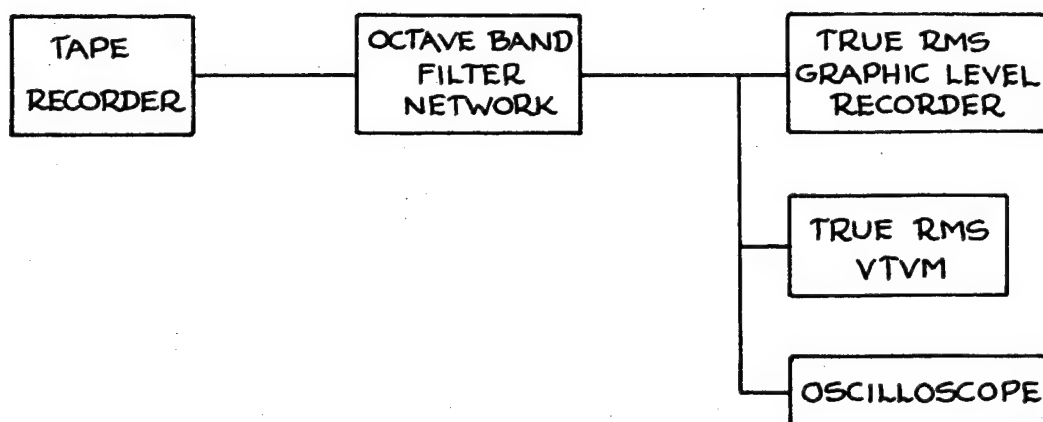


Figure 4. Analysis System

Section III

RESULTS

MEASURED DATA

Tables I thru VIII summarize the octave band SPL measured at the stations listed for the operating conditions specified. All data are fully corrected for response characteristics of all instrumentation and are considered to be accurate within ± 3 dB absolute and ± 2 dB relative. All internal insulating material has been removed from both the AC-119G and the AC-130A gunships and as a result the many bare metal reflecting surfaces inside the cargo compartment can cause SPL to vary significantly with small changes in microphone locations.

The AC-119G gunship is flown with the front door removed and the two rear clamshell doors removed. The AC-130A gunship is flown with the front door removed, the rear ramp down, and the overhead door up. This open condition coupled with the openings in the side of the aircraft where each weapon protrudes creates airflow from approximately 0 to 10 knots in velocity inside the cargo compartment at various locations. The wind direction is random and is affected partially by the attitude of the aircraft. A windscreen was used for all data runs to significantly eliminate the turbulence that normally would be generated around the microphone and would otherwise appear in the data as relatively low frequency noise.

The analyzed data were broken down into four data zones for each aircraft. These zones represent data runs grouped by operating conditions and/or locations in the aircraft.

AC-119G

Data Zone 0 (Table I) — Consists of four data runs made during taxi, take-off and METO climb.

Data Zone 1 (Table II) — Consists of four data runs made in the cargo compartment during cruise conditions with the GTPU operating.

Data Zone 2 (Table III) — Consists of four data runs made in the cargo compartment during cruise conditions with the GTPU not operating.

Data Zone 3 (Table IV) — Consists of four data runs made in the aft section of the cargo compartment near the miniguns during gunfiring with the GTPU and illuminator operating.

AC-130A

Data Zone 0 (Table V) — Consists of three data runs made in the forward section of the cargo compartment during taxi, take-off, and climb.

Data Zone 1 (Table VI) — Consists of all twelve ambient runs made at the stations specified.

Data Zone 2 (Table VII) — Consists of four data runs made at the aft gunner's station during various weapon mix firing configurations.

Data Zone 3 (Table VIII) — Consists of six data runs made in the forward cargo compartment during various weapon mix firing configurations.

Each data zone will be discussed separately in a following subsection of this report.

DAMAGE RISK CRITERIA

The hearing damage risk contours used in this evaluation are taken from a report of Working Group 46¹ entitled "Hazardous Exposure to Intermittent and Steady State Noise." Karl D. Kryter, Chairman. The phrase "damage risk contours" refers to curves showing various relations among sound pressure level, band center frequency of sound, and the temporal nature of exposure that will provide the damage risk to hearing specified in the following criterion. The basic criterion is that a sound environment will be deemed acceptable if it produces, on the average, a permanent sound or noise induced hearing loss in people after 10 years or more of nearly daily exposure of no more than 10 dB at 1000 Hz or below, nor more than 15 dB at 2000 Hz, or no more than 20 dB at 3000 Hz or above (ASA 1951 reference)². The present criterion is concerned only with the range of frequencies from 100 to 7000 Hz. This criterion allows less hearing loss at lower frequencies than at higher frequencies to provide greater protection for hearing in the frequency region containing the major portion of the energy found in the normal speech signal. If the SPL in any single band exceeds the damage risk contours, the overall noise can be considered as potentially unsafe.

Both the aircraft ambient and gunfiring environments are essentially broadband continuous noise and hence the damage risk contours for broadband, continuous noise were used. The high firing rate of the guns produces the continuous noise exposure as opposed to an intermittent noise exposure as is normally associated with slow rate gunfire. Peak factor analysis showed that instantaneous peak values do not exceed the root mean square value of the recorded gunfiring data by more than 12 dB, which is characteristic of random jet noise. Figures 5 and 6 show a comparison between the spectrum of the aircraft ambient noise and the aircraft ambient plus gunfiring noise at the same location in the aircraft. The broadband characteristics of the spectrum can readily be distinguished from these curves.

The damage risk contour used for the gunfiring noise is for a 6-minute continuous duration, one exposure per day. Although the guns will not be fired continuously for the full 6 minutes, this criterion is reasonable and provides a safety margin when considering the interrupted exposure. A continuous 6-minute exposure is somewhat more severe than any combination of short exposures, of about the same magnitude as the steady exposure, that total 6 minutes in any one day.

1. The National Academy of Science - National Research Council, Committee on Hearing, Bioacoustics, and Biomechanics (CHABA), was asked by the Office of the Surgeon General, U.S. Army, to reevaluate, on the basis of new knowledge, the question of damage risk criteria for exposure to sound. To this end, CHABA Working Group 46 was established. This Working Group has analyzed the research data and problems in this general area and has concluded that a new set of rules and recommendations can be prescribed with respect to damage risk criteria and contours for exposure to steady sound. These new rules take into account research data that were not available when U.S. Air Force Regulation 160-3 was published.

2. The ASA 1951 reference threshold level is defined in American Standard Specification for Audiometers for General Diagnostic purposes Z24.5-1951. This Specification may be obtained from The United States of America Standards Institute, 10 E. 40th Street, New York 16, N. Y. An excellent discussion of the ASA 1951 reference and the new ISO (International Standards Organization) Reference Zero is contained in the March 1964 edition of The Magazine of Standards.

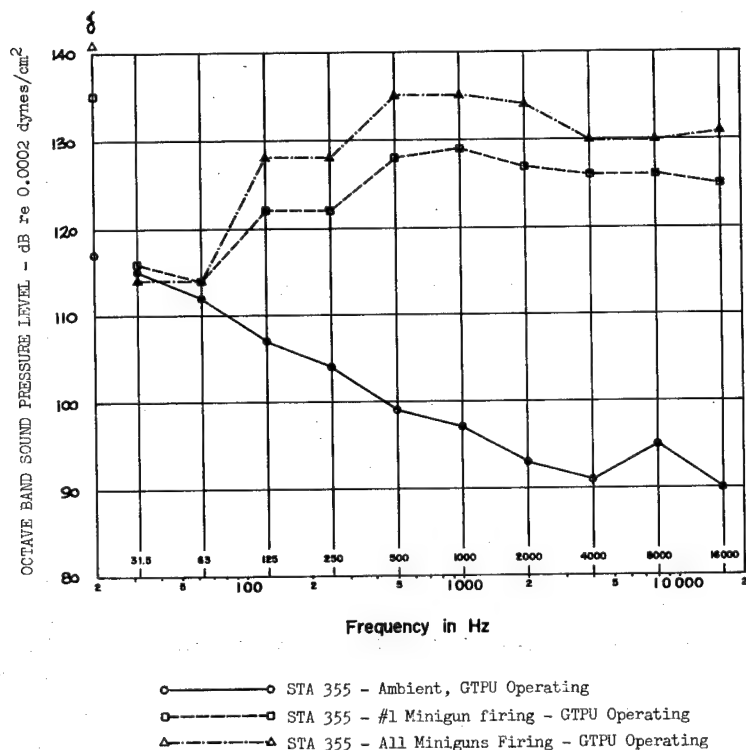


Figure 5. AC-119G Ambient Environment vs Ambient Plus Gunfiring Environment

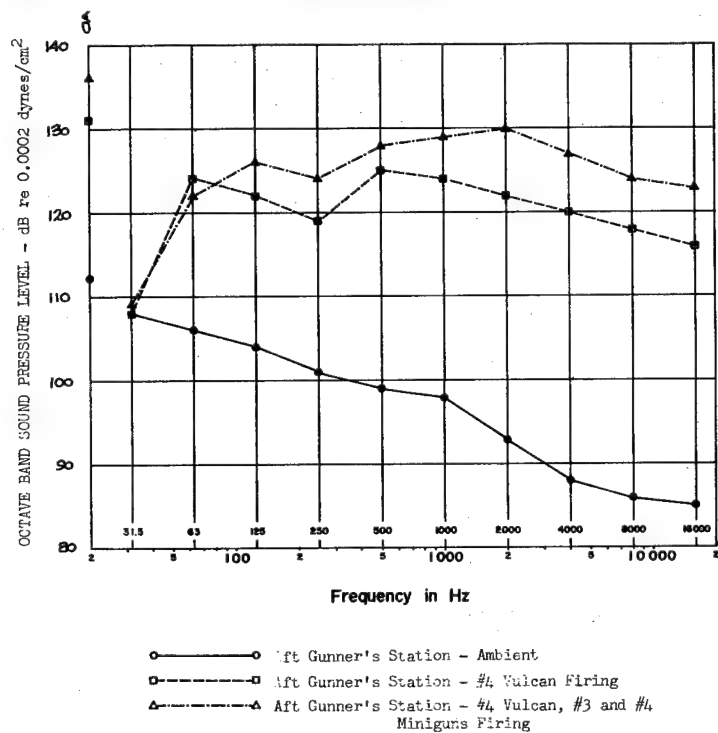


Figure 6. AC-130A Ambient Environment vs Ambient Plus Gunfiring Environment

AC-119G DATA**Data Zone 0**

The four data runs that make up this zone (Table I) were made in the forward section of the cargo compartment at stations 125 and 179. Station 125 is the second troop seat on the right side of the aircraft and station 179 is the fourth troop seat on the right side of the aircraft next to the GTPU. The runs were made at taxi, take-off and METO power settings. The * in Table I denotes the highest SPL in each octave band and these values determine the upper limit of the data zone. In this case, Run No. 2 contains the highest levels, which is to be expected since this run was made during take-off. The 31.5 and 63 Hz data points were not plotted because first, there are no damage risk criteria available below 100 Hz and second, protective equipment attenuation data is available only down to 125 Hz. It is the opinion of the Working Group who developed the damage risk contours that there is at the present time insufficient evidence to warrant extrapolating the damage risk contours as a function of frequency beyond the 100 to 7000 Hz frequency range. The SPL in these two bands should not present an unacceptable situation if the recommended protective equipment is used.

TABLE I. DATA ZONE 0, AC-119G No. 53-8089

Run No.	Measurement Station and Operating Conditions	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz										
		OA	31.5	63	125	250	500	1K	2K	4K	8K	16K
1.	Sta. 179, Rt Side of Cargo Compartment - Taxi Power, GTPU Operating	105	95	97	94	98	92	90	94	94	98	93
2.	Sta. 179, Rt Side of Cargo Compartment - Take-Off Power, GTPU Operating	132	109	126*	123*	130*	122*	115*	107*	101*	101*	100*
3.	Sta. 179, Rt Side of Cargo Compartment - METO Power, GTPU Operating	125	111*	120	118	121	111	103	97	95	100	95
4.	Sta. 125, Rt Side of Cargo Compartment - METO Power, GTPU Operating	126	111	123	113	121	109	101	95	92	93	88

*Highest level in data zone for each octave band.

Plotted in conjunction with the data zone is the damage risk contour for a 1½ minute or less continuous duration - one exposure per day. This criteria can be applied to the take-off condition which is the upper limit of the data zone. In figure 7 none of the data points are above the contour and hence do not constitute a potentially unsafe condition. Also plotted is the damage risk contour for a 10-minute continuous exposure - one exposure per day. This criteria can be applied to the METO climb condition shown by the dotted line in the data zone. Again none of the data points are above the contour and no potentially unsafe condition exists.

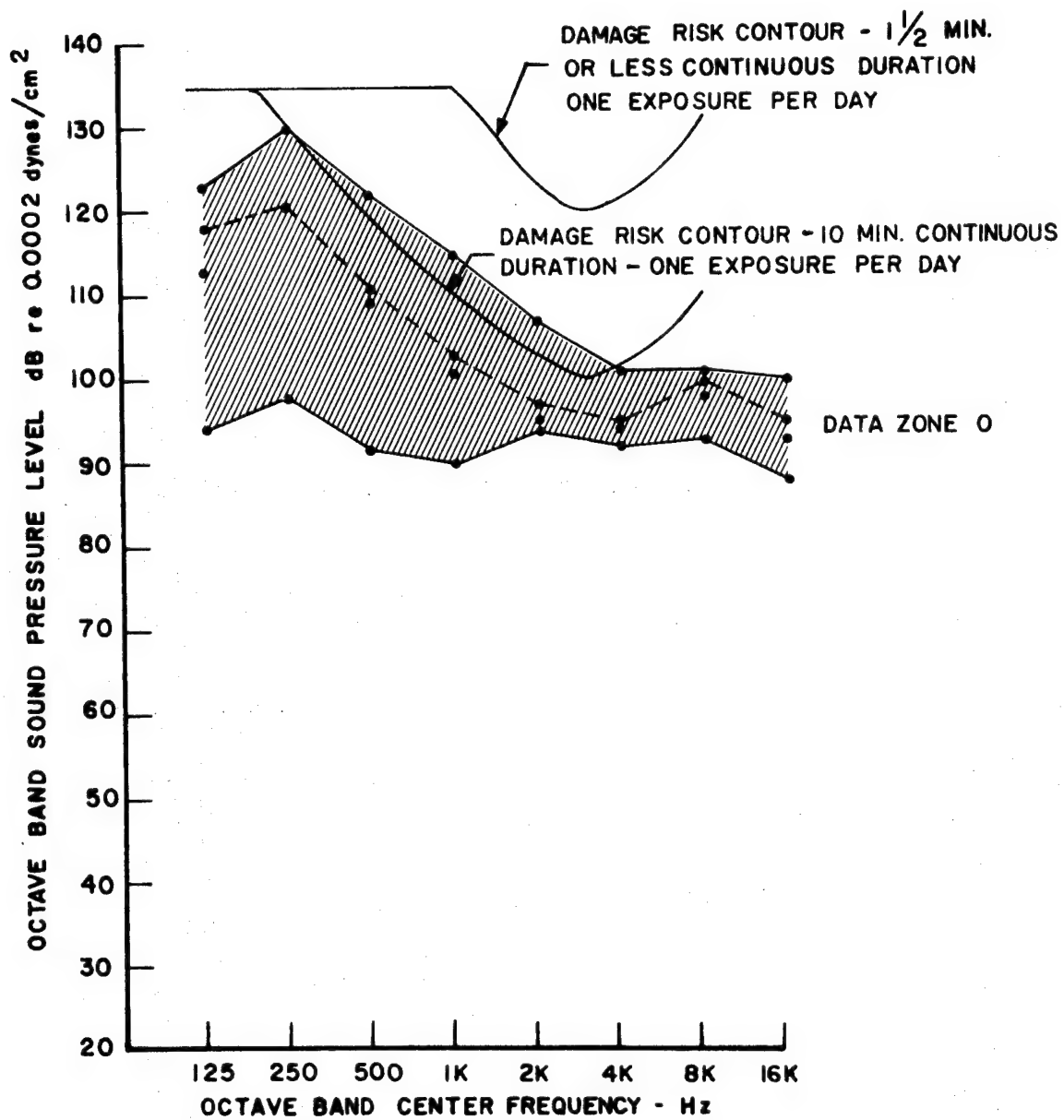


Figure 7. AC-119G Sound Pressure Levels In Cargo Compartment During Taxi, Take-Off, and Climb

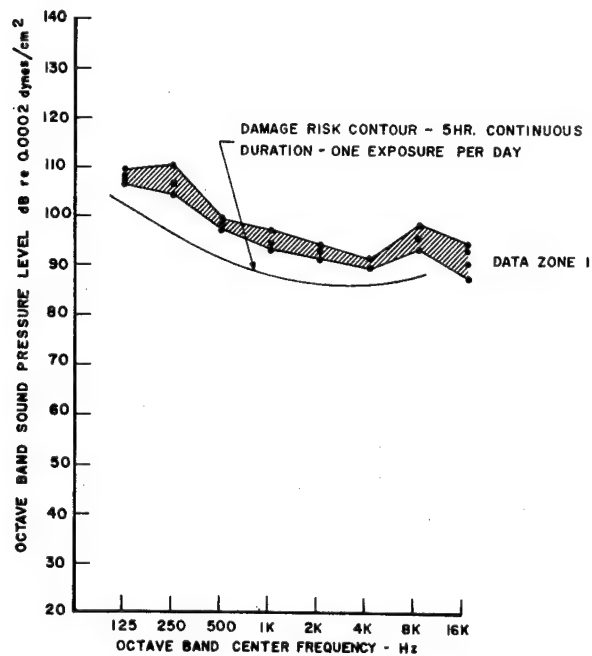
Data Zone 1

The four data runs that make up this zone (Table II) were made at stations 125 and 179 (the second and fourth troop seat on the right side of the cargo compartment), station 226 (the third troop seat on the left side of the cargo compartment), and station 355 (adjacent to the ammo can storage racks across from the No. 1 and No. 2 miniguns). The GTPU was operating during all of the runs. Again the 31.5 and 63 Hz data were not plotted and the comments regarding these points in the AC-119G Data Zone 0 section are applicable.

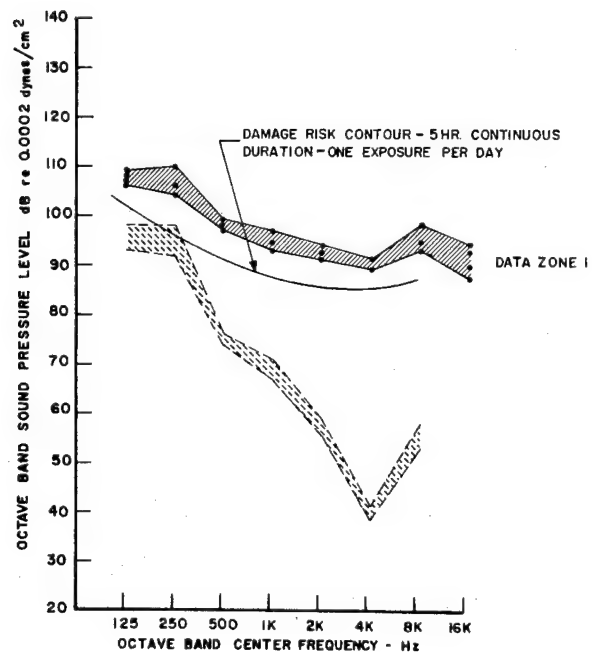
Plotted in conjunction with the data zone in figure 8a is the damage risk contour for a 5-hour continuous duration – one exposure per day. Based on information obtained at Lockbourne AFB, Ohio, the 5-hour mission is a realistic operational figure. In figure 8a all of the data points are above the contour and hence constitute a potentially unsafe condition. Figures 8b, 8c, 8d, and 8e show the data zone attenuated by four in-service protective devices; a Gentex HGU 2A/P Protective Helmet with Gentex ear cups, an H-157 Headset-Communication unit, Flents disposable ear plugs and V-51R ear plugs. The attenuated data zones show the SPL at the ear under the protective device, and the attenuation values used are the average attainable for each octave band assuming that the device is properly fit in or over the ear.

TABLE II. DATA ZONE 1, AC-119G No. 53-8089

Run No.	Measurement Location and Operating Conditions	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz									
		OA	31.5	63	125	250	500	1K	2K	4K	8K 16K
1.	Sta. 179, Rt Side of Cargo Compartment – Cruise, GTPU Operating	116	109	112	106	110	99	94	93	91	98 94
2.	Sta. 125, Rt Side of Cargo Compartment – Cruise, GTPU Operating	116	111	113	109	106	97	93	91	89	93 87
3.	Sta. 226, Left Side of Cargo Compartment – Cruise, GTPU Operating	117	108	114	108	110	98	94	94	91	98 93
4.	Sta. 355, Rt Side of Cargo Compartment – Cruise GTPU Operating	118	115	112	107	104	99	97	93	91	95 90

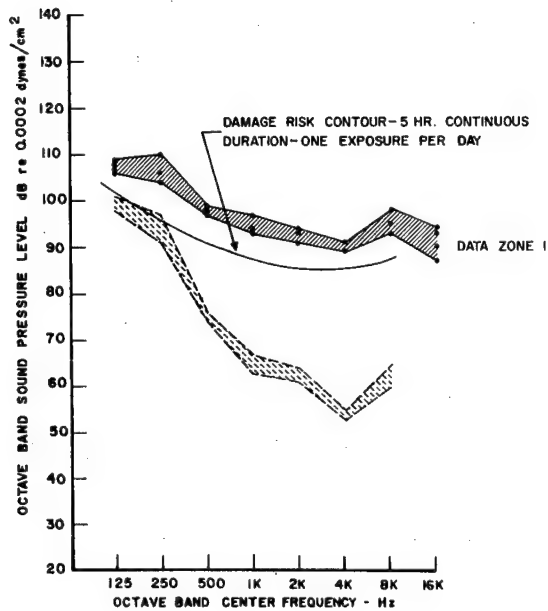


a. Basic Data

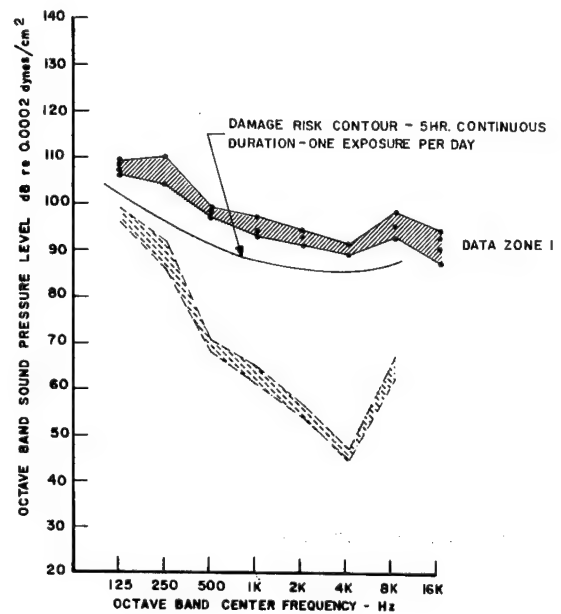


b. Basic Data Attenuated By Gentex HGU 2A/P with Gentex Ear Cups

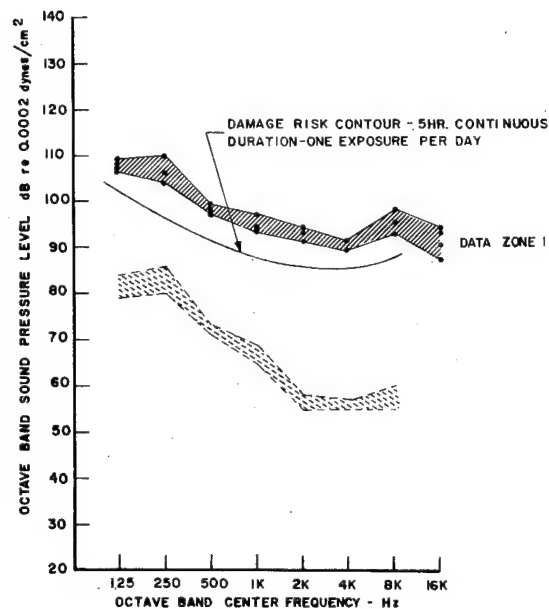
Figure 8. AC-119G Sound Pressure Levels In Cargo Compartment During Cruise — GTPU Operating (1430 BHP, 2100 RPM, 3000 Feet PA)



c. Basic Data Attenuated By H-157 Communication Unit



d. Basic Data Attenuated By Flents Disposable Ear Plugs



e. Basic Data Attenuated By V-51R Ear Plugs

Figure 8. Continued

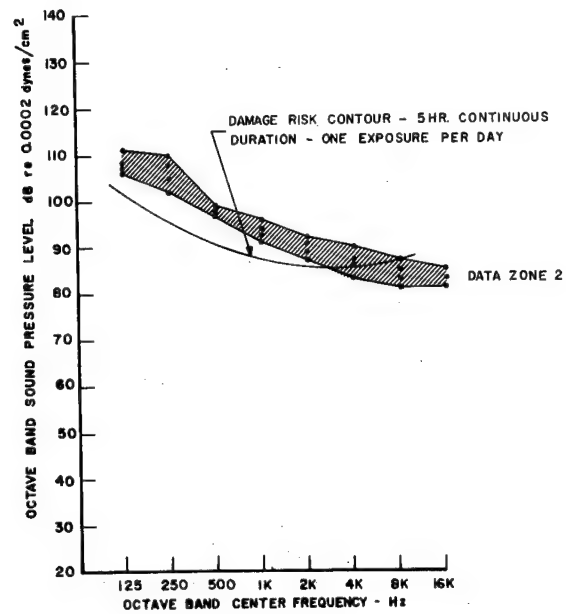
Data Zone 2

The four data runs that make up this zone (Table III) were made at the same locations as the four runs in Data Zone 1, however, the GTPU was not operating. Comparison of the levels in the 8 kHz octave band with the GTPU operating and not operating show an 8-15 dB decrease with the GTPU not operating. In the 16 kHz octave band, the decrease spread is from 6 to 13 dB. This is to be expected because turbine noise is relatively high frequency and even though the turbine is vented overboard, much of the turbine whine is in the cargo compartment. Again the 31.5 and 63 Hz data were not plotted and the comments regarding these points in the AC-119G Data Zone 0 section are applicable.

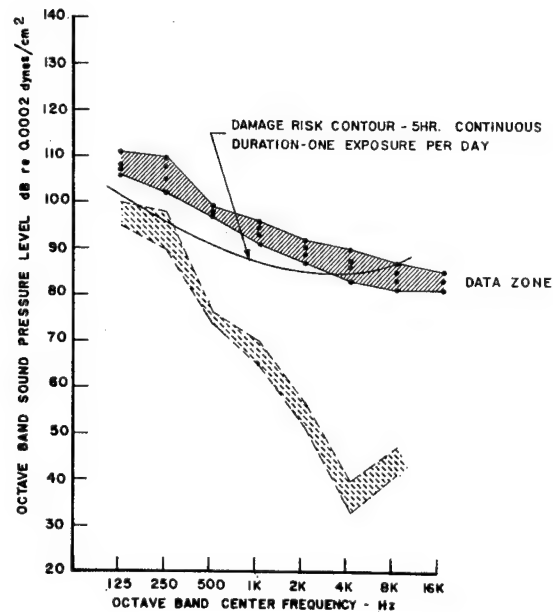
Plotted in conjunction with the data zone in figure 9a is the damage risk contour for a 5-hour continuous duration — one exposure per day. In the figure a majority of the data points are above the contour and hence constitute a potentially unsafe condition. Figures 9b, 9c, 9d, and 9e show the data zone attenuated by four in-service protective devices. The attenuated data zones show the SPL at the ear under the protective device and are valid only if the protective device is fit properly in or over the ear.

TABLE III. DATA ZONE 2, AC-119G No. 53-8089

Run No.	Measurement Station and Operating Conditions	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz										
		OA	31.5	63	125	250	500	1K	2K	4K	8K	16K
1.	Sta. 179, Rt Side of Cargo Compartment — Cruise, GPTU Off	115	107	111	106	108	98	93	89	86	83	81
2.	Sta. 125, Rt Side of Cargo Compartment — Cruise, GPTU Off	117	110	114	111	105	97	91	87	83	81	81
3.	Sta. 226, Left Side of Cargo Compartment — Cruise, GPTU Off	117	109	114	108	110	99	94	91	87	85	85
4.	Sta. 335, Ft. Side of Cargo Compartment — Cruise, GPTU Off	117	115	111	107	102	98	96	92	90	87	83

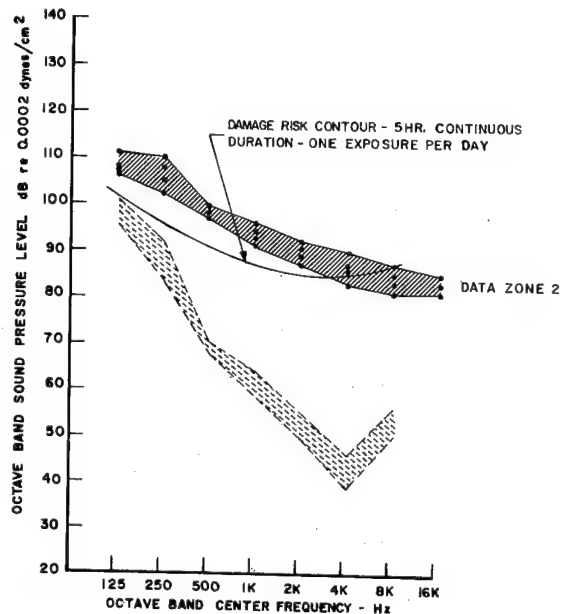
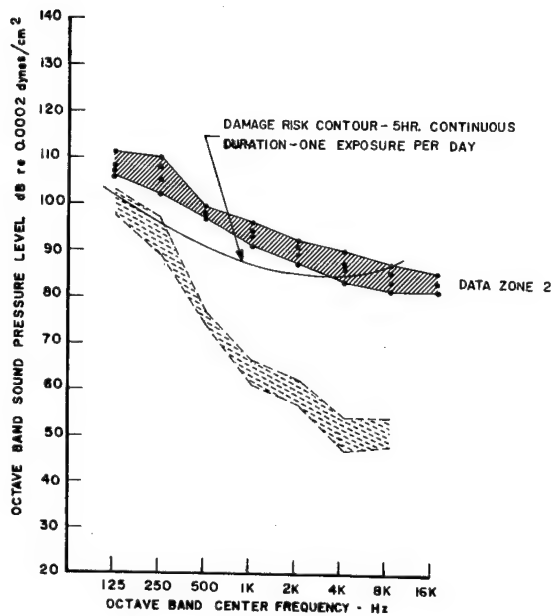


a. Basic Data



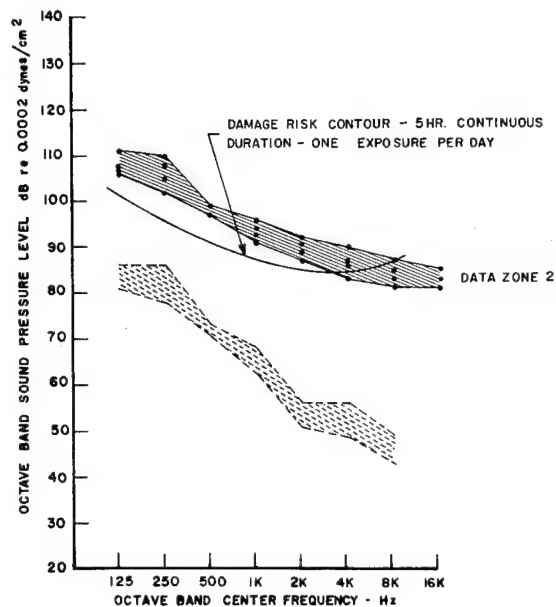
b. Basic Data Attenuated By Gentex HGU 2A/P with Gentex Ear Cups.

Figure 9. AC-119G Sound Pressure Levels In Cargo Compartment During Cruise — GTPU Off (1430 BHP, 2100 RPM, 3000 Feet PA)



c. Basic Data Attenuated By H-157
Communication Unit

d. Basic Data Attenuated By Flents Disposable
Ear Plugs



e. Basic Data Attenuated By V-51R Ear Plugs

Figure 9. Continued

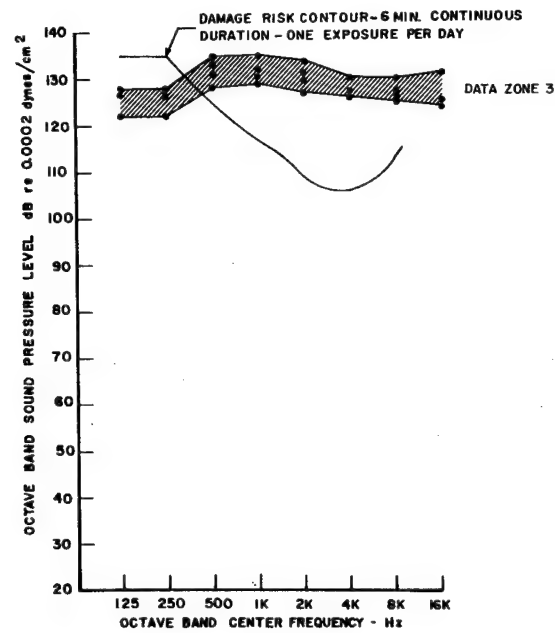
Data Zone 3

The four data runs that make up this zone (Table IV) were made in the aft section of the cargo compartment in close proximity to the miniguns. During these gunfiring data runs, the GTPU and illuminator were operating. Again, the 31.5 and 63 Hz data were not plotted and the comments regarding these points in the AC-119G Data Zone 0 section are applicable.

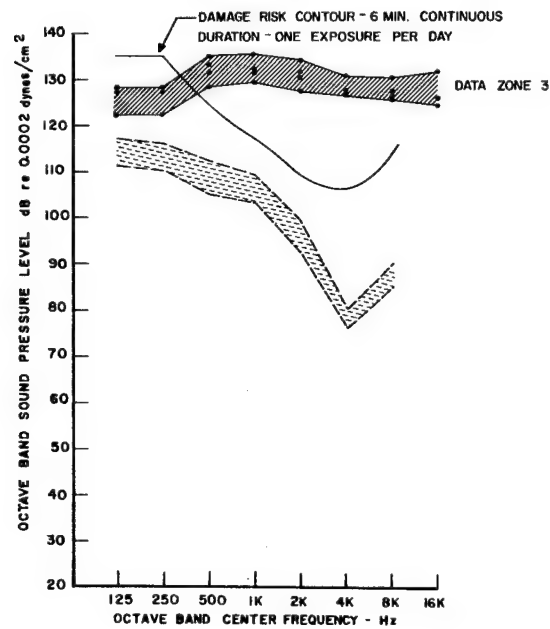
Plotted in conjunction with the data zone in figure 10a is the damage risk contour for a 6-minute continuous duration – one exposure per day. The 6-minute figure was arrived at by determining the amount of time required to fire out all the 7.62 mm ammo that is carried on the aircraft. Other pertinent comments regarding the selection of the 6-minute continuous duration damage risk contour are contained in the Damage Risk Criteria section. Figures 10b, 10c, 10d, and 10e show the data zone attenuated by four in-service protective devices. The attenuated data zones show the SPL at the ear under the protective device and are valid only if the protective device is fit properly in or over the ear.

TABLE IV. DATA ZONE 3, AC-119G No. 53-8089

Run No.	Measurement Location and Operating Conditions	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz										
		OA	31.5	63	125	250	500	1K	2K	4K	8K	16K
1.	Sta. 355, Side of Cargo Compartment Near Ammo Can Storage Racks – Head Level – #1, #2, #3 and #4 Miniguns Firing – Illuminator and GTPU On	141	114	114	128	128	135	135	134	130	130	131
2.	Illuminator Operator's Station, Head Level – #4 Minigun Firing – Illuminator and GTPU On	138	112	115	127	127	131	131	130	127	125	124
3.	Sta. 335, Left Side of Cargo Compartment Between #1 and #2 Miniguns, Head Level – #1 Minigun Firing – Illuminator and GTPU On	138	116	117	122	127	133	132	131	127	127	124
4.	Sta. 355, Rt Side of Cargo Compartment Near Ammo Can Storage Racks – Head Level – #1 Minigun Firing – Illuminator and GTPU On	135	116	114	122	122	128	129	127	126	126	125

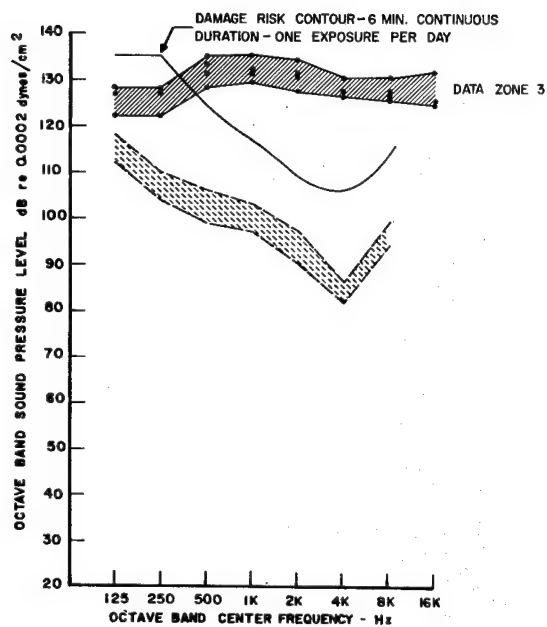
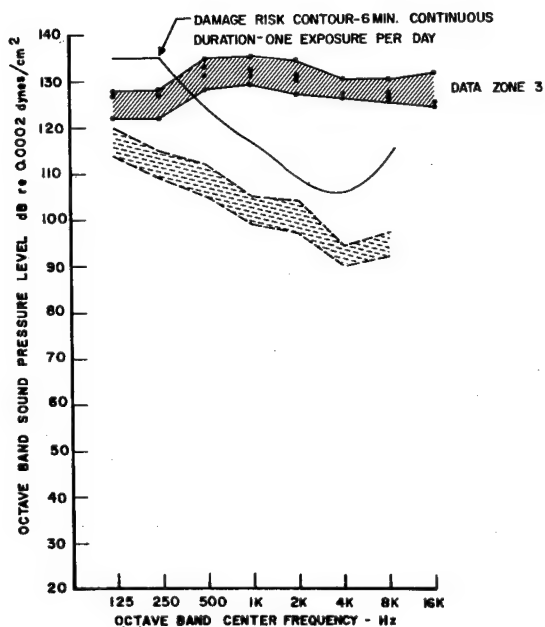


a. Basic Data



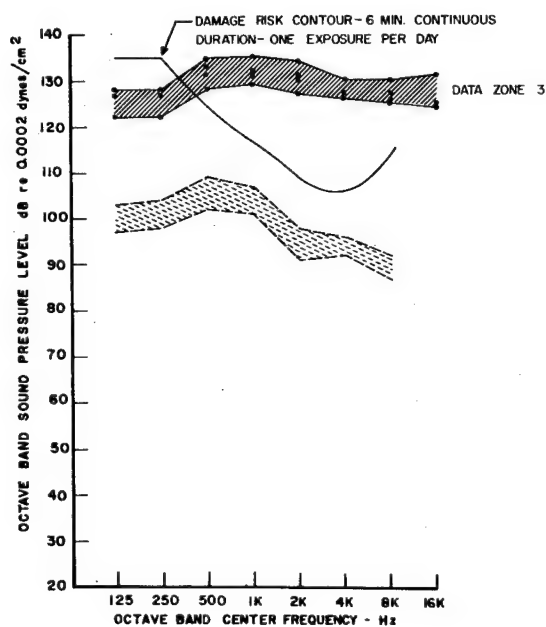
b. Basic Data Attenuated By Gentex HGU 2A/P with Gentex Ear Cups

Figure 10. AC-119G Sound Pressure Levels in Cargo Compartment During Gunfiring



c. Basic Data Attenuated By H-157 Communication Unit

d. Basic Data Attenuated By Flents Disposable Ear Plugs



e. Basic Data Attenuated By V-51R Ear Plugs

Figure 10. Continued

AC-130A DATA

Data Zone 0

The three data runs that make up this zone (Table V) were made in the cargo compartment just aft of the crew compartment in cargo seat No. 5. The runs were made at taxi, take-off, and climb power settings. All runs were made with the rear ramp up and the overhead door down, which is not the normal flight configuration, however, due to an equipment malfunction, the ramp or overhead door could not be operated. The 31.5 and 63 Hz data points were not plotted because first, there are no damage risk criteria available below 100 Hz and second, protective equipment attenuation data are available only down to 125 Hz. It is the opinion of the Working Group that developed the damage risk contours that there is at the present time insufficient evidence to warrant extrapolating the damage risk contours as a function of frequency beyond the 100 to 7000 Hz frequency range. The SPL in these two bands present an unacceptable situation if the recommended protective equipment is used.

Plotted in conjunction with the data zone is the damage risk contour for a 1½ minute or less continuous duration – one exposure per day. This criteria can be applied to the take-off condition. Also plotted is the damage risk contour for a 10-minute continuous exposure – one exposure per day. This criteria can be applied to the climb condition. As can be seen from figure 11, none of the data points are above either of the damage risk contours, and no potentially unsafe condition exists.

TABLE V. DATA ZONE 0, AC-130A No. 54-1625

Run No.	Measurement Station and Operating Conditions	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz										
		OA	31.5	63	125	250	500	1K	2K	4K	8K	16K
1.	#5 Seat – Fwd Compartment – Taxi Power	111	97	109	101	101	98	98	91	88	92	93
2.	#5 Seat – Fwd Compartment – Take-Off Power	120	107	118	113	105	98	97	93	89	89	88
3.	#5 Seat – Fwd Compartment – Climb Power	121	110	120	112	108	103	99	95	91	87	86

NOTE: All measurements taken with rear ramp up and overhead door down.

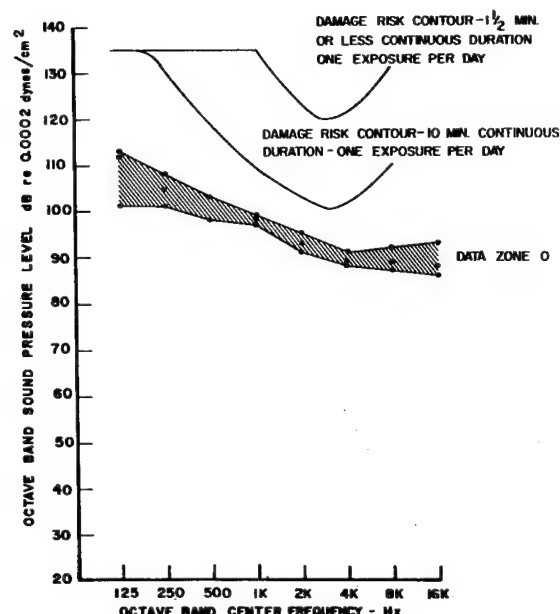
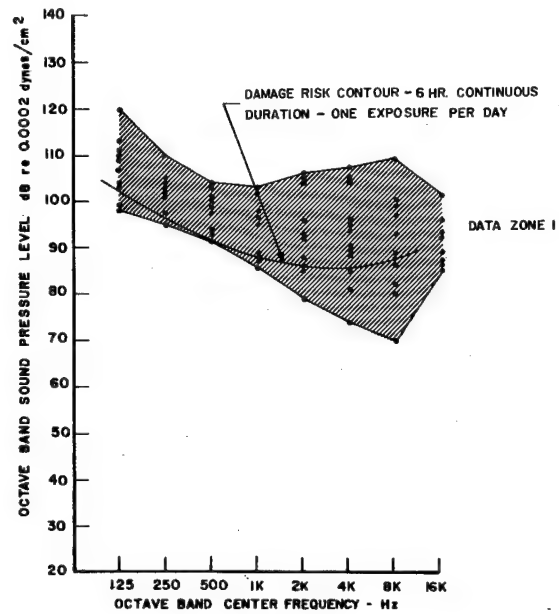


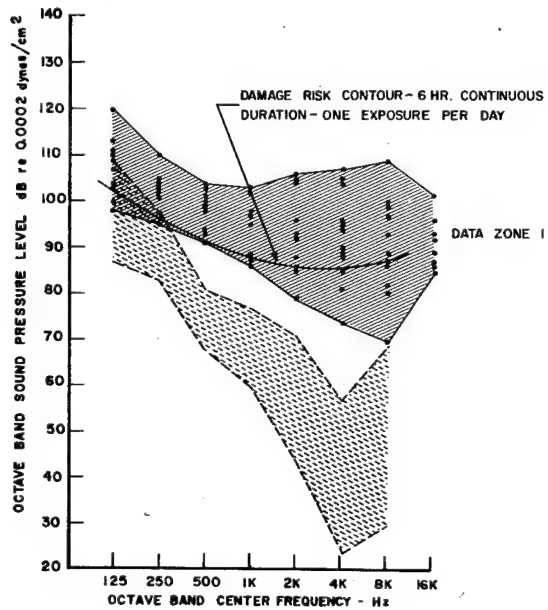
Figure 11. AC-130A Sound Pressure Levels In Forward Compartment During Taxi, Take-Off, and Climb

Data Zone 1

The twelve ambient data runs in this zone (Table VI) were made while the aircraft was flying at an airspeed of 150 KIAS and a pressure altitude of 2500 feet. The runs were made with the rear ramp down and the overhead door up, the normal flight configuration. The twelve data points for each octave band were plotted against the SPL in that band, and the boundaries of the data zone were thus determined. As can be seen from figure 12a the spread at the 8 kHz octave band is 39 dB while at 500 Hz, the spread is only 13 dB. The * in Table VI denotes the highest SPL in each octave band, and these values determine the upper limit of the data zone. In this case, the SPL at the scanner's station with the hatch removed were the highest levels except for the 2

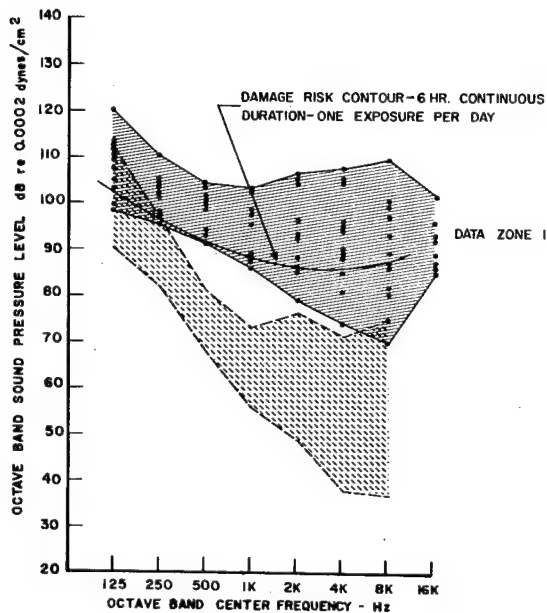


a. Basic Data

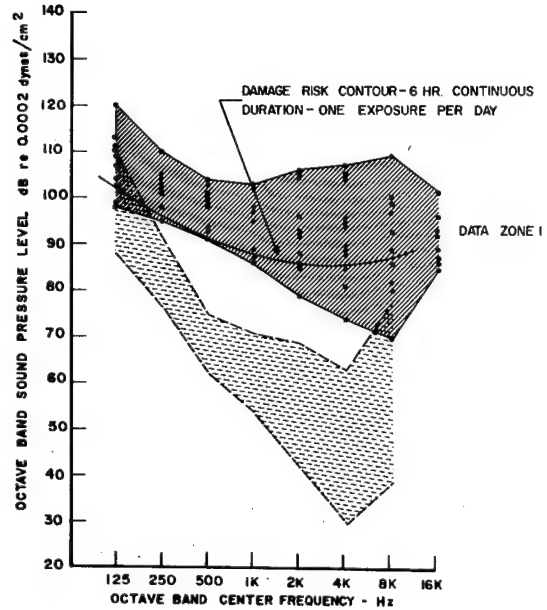


b. Basic Data Attenuated By Gentex HGU 2A/P with Gentex Ear Cups

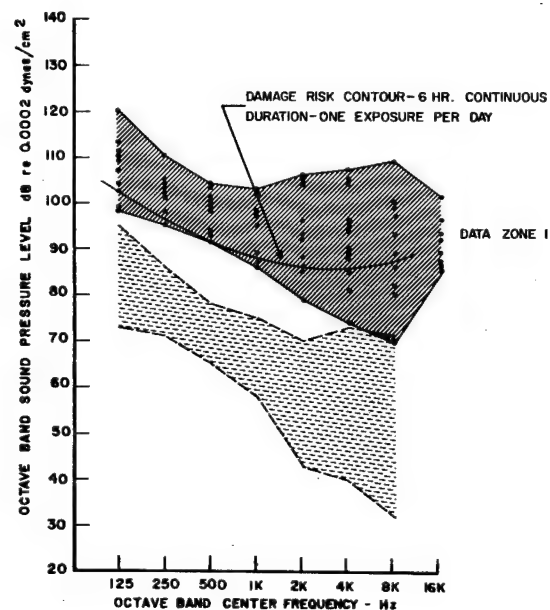
Figure 12. AC-130A Sound Pressure Levels During Cruise
(150 KIAS, 2500 Feet PA)



c. Basic Data Attenuated By H-157 Communication Unit



d. Basic Data Attenuated By Flents Disposable Ear Plugs



e. Basic Data Attenuated By V-51R Ear Plugs

Figure 12. Continued

kHz and 4 kHz octave bands that were highest at the illuminator operator's station. The high levels at the scanner's station are due primarily to engine noise, propeller noise, and wind noise while the high levels in the two bands at the illuminator operator's station are most likely due to engine turbine noise and wind noise. The addition of the wind deflector on the leading edge of the scanner's hatch should substantially reduce the wind noise at that station. Again, the 31.5 and 63 Hz octave band data were not plotted, and the comments regarding these points in the AC-130A Data Zone 0 section are applicable. However, in Table VI the 63 Hz octave band contains higher

TABLE VI. DATA ZONE 1, AC-130A No. 54-1625

Run No.	Measurement Station and Operating Conditions	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz										
		OA	31.5	63	125	250	500	1K	2K	4K	8K	16K
1.	Pilot's Station — Head Level Cruise — 150 KIAS, 2500 Ft. PA	112	109	104	103	98	91	87	86	85	80	N.F.
2.	Navigator's Station — Head Level Cruise — 150 KIAS, 2500 Ft. PA	113	106	111	104	98	94	88	85	81	82	N.F.
3.	NOD Operator's Station — Head Level Cruise — 150 KIAS 2500 Ft. PA	123	109	122	111	105	101	97	93	89	89	85
4.	Scanner's Station — Head Level Cruise — 150 KIAS, 2500 Ft. PA	123	112	122	109	103	98	95	92	90	87	86
5.	Scanner's Station — Hatch Removed Head Level Cruise — 150 KIAS 2500 Ft. PA	129	115*	128*	120*	110*	104*	103*	104	104	109*	101*
6.	#3 Seat — Fwd Compartment — Scanner's Hatch Removed — Head Level Cruise — 150 KIAS, 2500 Ft. PA	117	108	113	113	102	99	97	96	96	97	89
7.	Aisle Adjacent to #1 and #2 Mini- guns — Head Level Cruise — 150 KIAS, 2500 Ft. PA	115	109	112	110	104	100	98	96	95	93	87
8.	Adjacent to Rear Door — Head Level Cruise — 150 KIAS, 2500 Ft. PA	119	109	117	104	104	103	102	105	105	99	96
9.	Illuminator Operator's Station — Head Level Cruise — 150 KIAS, 2500 Ft. PA	115	108	108	107	105	103	102	106*	107*	100	92
10.	Aft Gunner's Station — Head Level Cruise — 150 KIAS, 2500 Ft. PA	112	108	106	104	101	99	98	93	88	86	85
11.	Radar Operator's Station — Inside Booth — Door Open — Head Level Cruise — 150 KIAS, 2500 Ft. PA	110	105	108	98	95	93	89	88	85	80	N.F.
12.	Radar Operator's Station — Inside Booth — Door Closed — Head level Cruise — 150 KIAS, 2500 Ft. PA	108	101	107	99	95	91	86	79	74	70	N.F.

NOTE: All measurements taken with rear ramp down and overhead door up.

*Highest level in data zone for each octave band.

levels at the stations closest to the vertical plane of the propellers and/or openings such as are present at the NOD operator and scanner's station.

Plotted in conjunction with the data zone is the damage risk contour for a 6-hour continuous duration — one exposure per day. In figure 12a a majority of the data points are above the contour and hence constitute a potentially unsafe condition. Figures 12b, 12c, 12d, and 12e show the data zone attenuated by four in-service protective devices; a Gentex HGU 2A/P Protective Helmet with Gentex ear cups, an H-157 Headset Communication Unit. Flents disposable ear plugs and V-51R ear plugs. The attenuated data zones show the SPL at the ear under the protective device, and the attenuation values used are the average attainable for each octave band assuming that the device is properly fit in or over the ear.

Data Zone 2

The four data runs that make up this zone (Table VII) were made at the aft gunner's station during firing of the No. 2, No. 3, and No. 4 miniguns and the No. 4 vulcan fired separately or in various combinations. The aft gunner's station was considered to be in the area of the spent casings bin directly behind the No. 3 and No. 4 vulcan. As can be seen from figure 13a, the spread of the data zone is fairly constant throughout the frequency range. The * in table VII denotes the highest SPL in each octave band and these values determine the upper limit of the data zone. In this case, Run No. 3 contains the highest levels that are to be expected since the No. 3 and No. 4 miniguns and the No. 4 vulcan were firing. Again, the 31.5 and 63 Hz data were not plotted and the comments regarding these points in the AC-130A Data Zone 0 section are applicable.

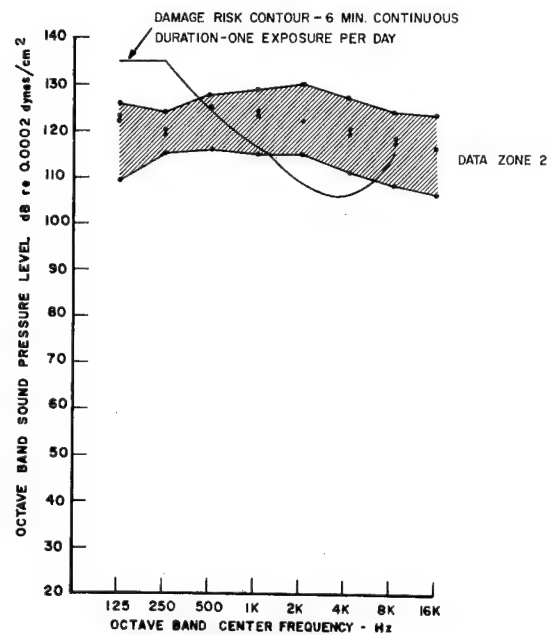
Plotted in conjunction with the data zone in figure 13a is the damage risk contour for a 6-minute continuous duration — one exposure per day. The 6-minute figure was arrived at by determining the number of rounds of 7.62 mm and 20 mm ammunition that can be carried aboard the aircraft, and knowing the firing rate of the weapons (3000 round/min for the 7.62 mm miniguns and 2500 rounds/min for the 20 mm vulcans), the maximum firing duration can be determined. In figure 13a a majority of the data points are above the contour and hence constitute a potentially unsafe condition. Figure 13b, 13c, 13d, and 13e show the data zone attenuated by the four in-

TABLE VII. DATA ZONE 2, AC-130A No. 54-1625

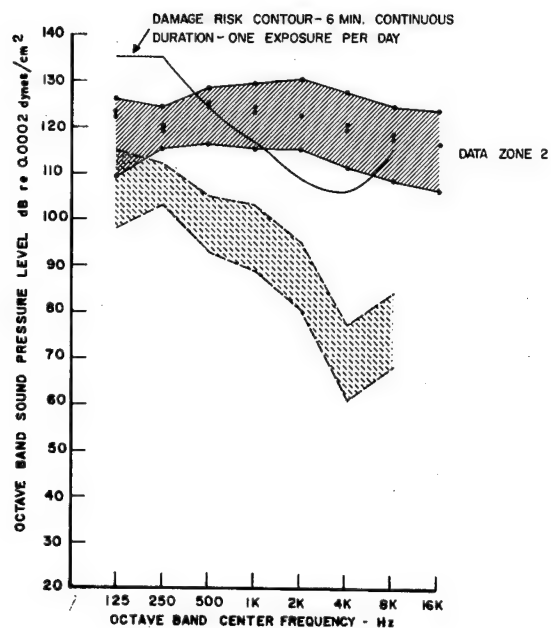
Run No.	Measurement Station and Operating Condition	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz										
		OA	31.5	63	125	250	500	1K	2K	4K	8K	16K
1.	Aft Gunner's Station — Head Level — #4 Vulcan Firing	131	108	124*	122	119	125	124	122	120	118	116
2.	Aft Gunner's Station — Head Level — #4 Vulcan, #2 Minigun Firing	131	106	121	123	120	124	123	122	119	117	116
3.	Aft Gunner's Station — Head Level — #4 Vulcan, #3 and #4 Miniguns Firing	136	109*	122	126*	124*	128*	129*	130*	127*	124*	123*
4.	Aft Gunner's Station — Head Level — #2 Minigun Firing	122	107	108	109	115	116	115	115	111	108	106

NOTE: All measurements taken with rear ramp down and overhead door up.
Firing rates: 7.62 mm miniguns — 3000 rounds/min.
20 mm vulcans — 2500 rounds/min.

*Highest level in data zone for each octave band.

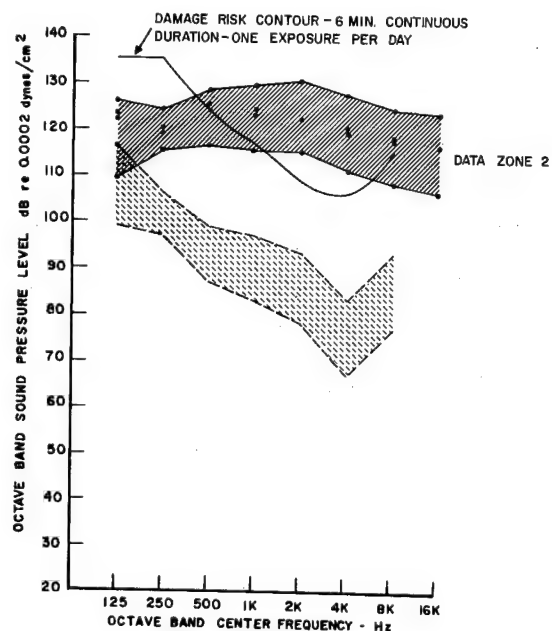
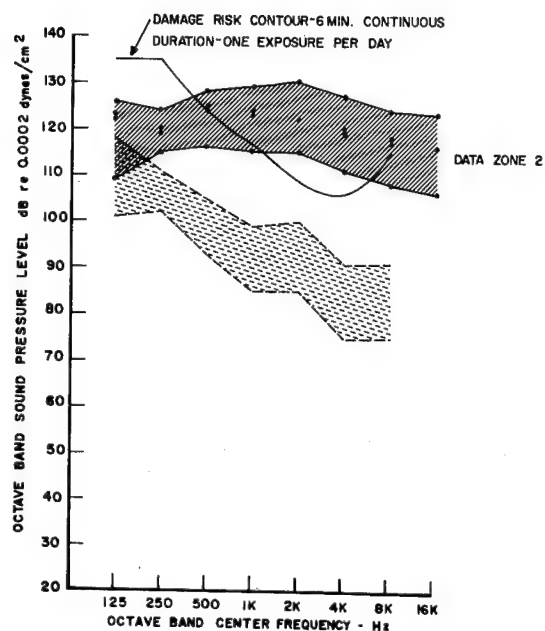


a. Basic Data



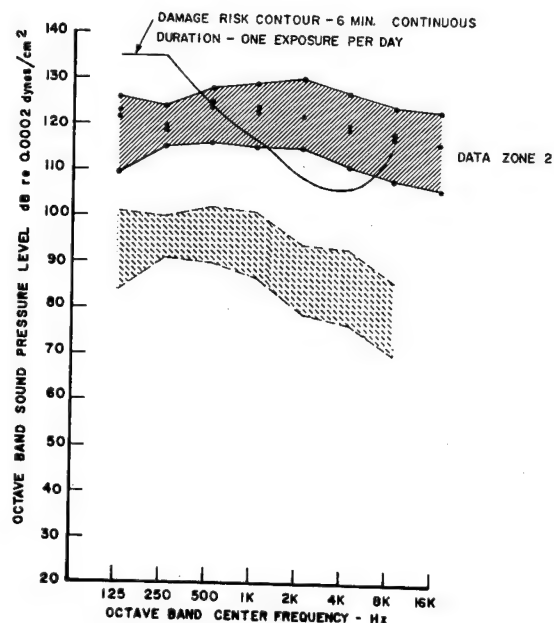
b. Basic Data Attenuated By Gentex HGU 2A/P with Gentex Ear Cups

**Figure 13. AC-130A Sound Pressure Levels In Aft Compartment
During Gunfiring**



c. Basic Data Attenuated By H-157 Communication Unit

d. Basic Data Attenuated By Flents Disposable Ear Plugs



e. Basic Data Attenuated By V-51R Ear Plugs

Figure 13. Continued

service protection devices. The attenuated data zones show the SPL at the ear under the protective device and the attenuation values used are the average attainable for each octave band assuming that the device is properly fit in or over the ear.

Data Zone 3

The six data runs that make up this zone (Table VIII) were made in the forward cargo compartment during firing of the No. 1 and No. 2 miniguns and No. 1 and No. 2 vulcans as well as the data run with all eight weapons firing simultaneously made at the aisle position adjacent to the No. 1 and No. 2 miniguns. The forward gunner's station was considered to be in the area of the spent casings bin directly behind the No. 1 and No. 2 vulcans. As was the case with Data Zone 2, the spread of the data zone was fairly constant throughout the frequency range. The * in Table VIII denotes the highest SPL in each octave band, and these values determine the upper limit of the data zone. In this case, the highest levels are during firing of all eight weapons, which is to be expected. Again, the 31.5 and 63 Hz data points were not plotted, and the comments regarding this in the AC-130A Data Zone 0 section are applicable.

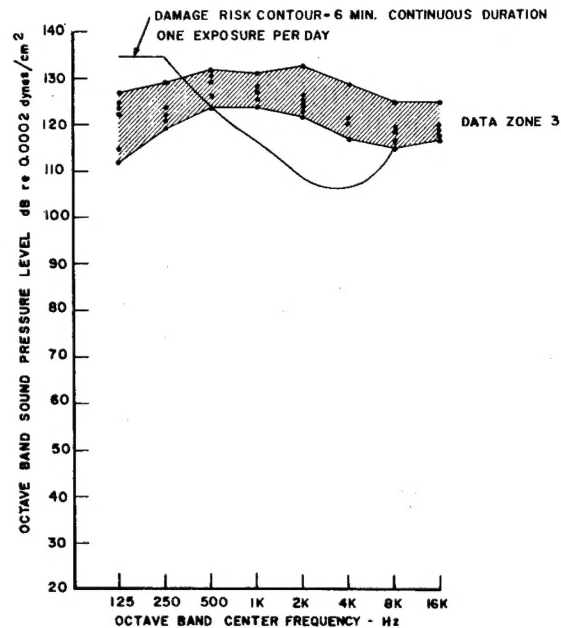
Plotted in conjunction with the data zone in figure 14a is the damage risk contour for a 6-minute continuous duration — one exposure per day. Figure 14a shows a majority of the data points are above the contour and hence constitute a potentially unsafe condition. Figures 14b, 14c, 14d, and 14e show the data zones attenuated by four in-service protective devices. The attenuated data zones show the SPL at the ear under the protective device and are valid only if the protective device is fit properly in or over the ear.

TABLE VIII. DATA ZONE 3, AC-130A No. 54-1625

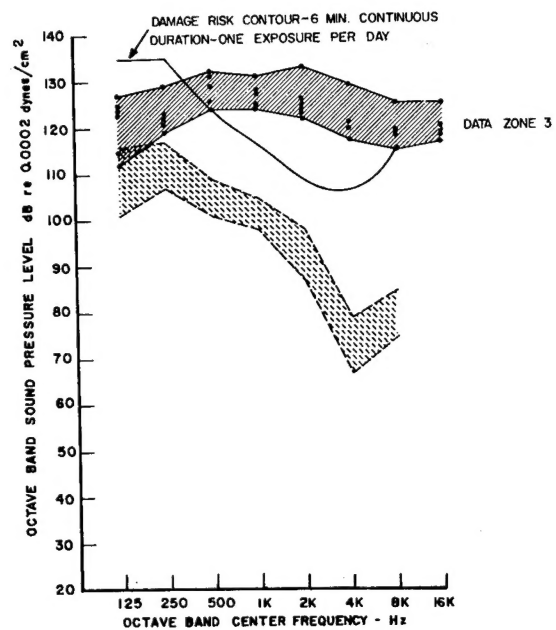
Run No.	Measurement Station and Operating Conditions	Octave Band SPL-dB re 0.0002 dynes/cm ² Frequency-Hz										
		OA	31.5	63	125	250	500	1K	2K	4K	8K	16K
1.	Fwd Gunner's Station — Head Level #1 and #2 Vulcans, #1 and #2 Miniguns Firing	134	110	117	124	122	129	128	124	121	119	119
2.	NOD Operator's Station—Head Level — #1 and #2 Vulcans, #1 and #2 Miniguns Firing	136	124*	128*	125	129*	131	125	123	120	118	118
3.	Aisle Adjacent to #1 and #2 Mini- guns — Head Level — #1 and #2 Miniguns Firing	129	108	116	112	119	124	124	122	117	115	117
4.	Aisle Adjacent to #1 and #2 Mini- guns Firing (High Rate of Fire 6000 Rounds/Min)	133	108	116	115	123	126	128	125	120	119	120
5.	Seat #2 in Fwd Compartment — Head Level — #1 and #2 Miniguns Firing	133	106	111	123	121	129	127	126	121	119	119
6.	Aisle Adjacent to #1 and #2 mini- guns — All Weapons Firing	139	115	122	127*	129*	132*	131*	133*	129*	125*	125*

NOTE: All measurements taken with aft ramp down and overhead door up.
Firing rates: 7.62 mm miniguns — 3000 rounds/min except run No. 4
200 mm vulcan — 2500 rounds/min.

*Highest level in data zone for each octave band.

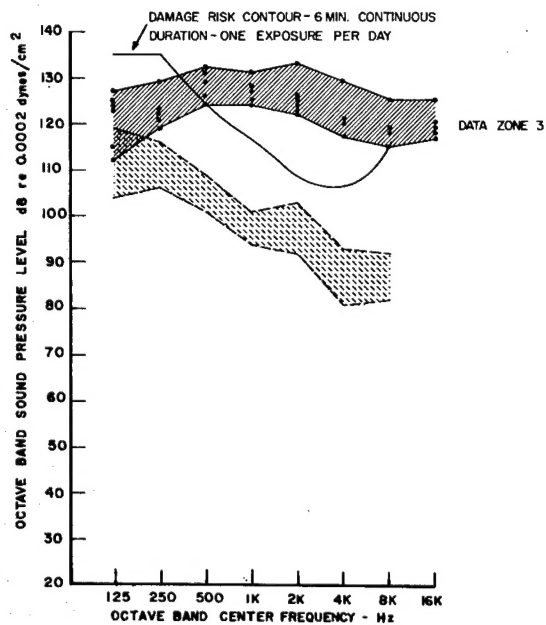


a. Basic Data

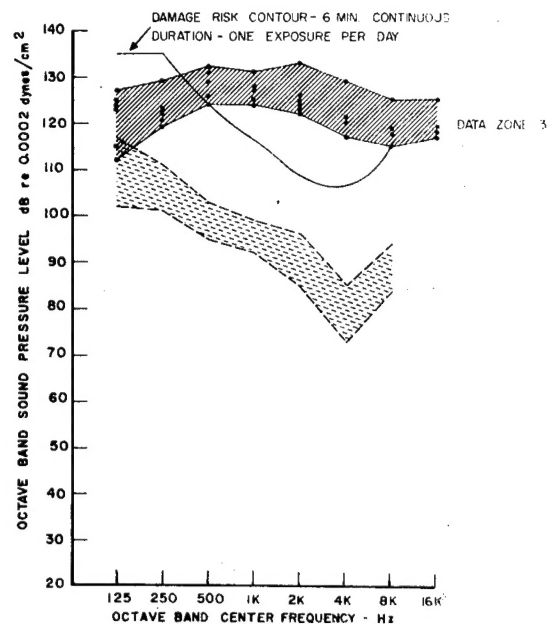


b. Basic Data Attenuated By Gentex HGU 2A/P with Gentex Ear Cups

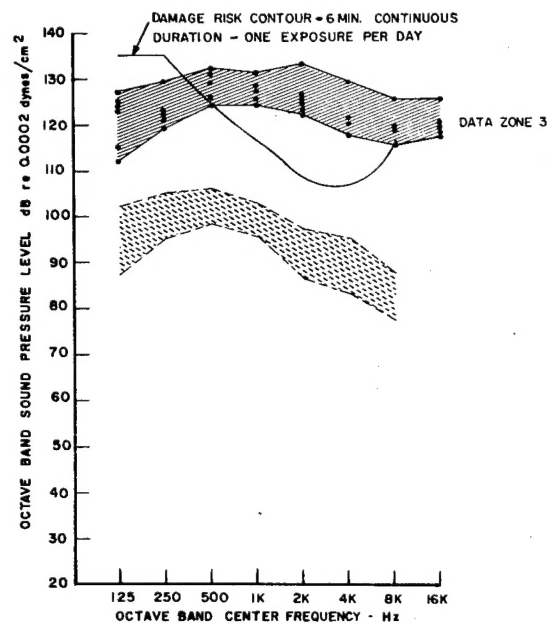
Figure 14. AC-130A Sound Pressure Levels In Forward Compartment During Gunfiring



c. Basic Data Attenuated By H-157 Communication Unit



d. Basic Data Attenuated By Flents Disposable Ear Plugs



e. Basic Data Attenuated By V-51R Ear Plugs
Figure 14. Continued

Section IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The ambient noise SPL in the AC-119G and the AC-130A are high enough to require full time ear protection.
2. Although the SPL during gunfiring are higher than the ambient levels in both the AC-119G and the AC-130A, the much shorter exposure duration makes the ambient levels more severe from the standpoint of hearing loss.
3. When the GTPU is operating in the AC-119G, the SPL in the 8 kHz and 16 kHz octave bands are considerably higher and are dependent on distance from the GTPU.
4. Addition of the ¼ inch nylon ballistic felt curtains and the wind deflector on the leading edge of the scanner's hatch in the AC-130A should reduce the SPL in the aircraft. This conclusion is based on ambient measurements taken in AC-130A No. 54-1623 at Lockbourne AFB, Ohio which had the curtains installed.
5. Use of present inflight sound protection devices will adequately protect crewmembers in the AC-119G and AC-130A in both the ambient and gunfiring environments.

RECOMMENDATIONS

1. Ear protection as provided by standard inflight head gear should be used at all times by crewmembers flying in the AC-119G and the AC-130A. Ground communication headset units should not be used in flight since the receivers are not pressure compensated.
2. At the crew stations requiring voice communication or interphone monitoring, the Gentex HGU 2A/P Protective Helmet with Gentex ear cups or the H-157 Headset-Communication Unit can be used.
3. If any crewmember experiences discomfort due to the noise environment when utilizing any standard inflight head gear, earplugs should be used in conjunction with the over-the-ear item being used to provide increased comfort and protection.
4. When earplugs are utilized, they should be inserted after the aircraft reaches level-off altitude and removed prior to any appreciable descent. Standard earplugs are not pressure compensated and should not be in the ear canal during marked pressure changes due to changes in aircraft altitude.
5. Standard inflight head gear other than that described in this evaluation can also be used during AC-119G and AC-130A missions. The attenuation data by octave band for the items not included in this report should be applied to the data zones for the particular aircraft/crew station conditions. When the levels in any of the octave bands exceed the damage risk contour after the attenuation values have been applied to the zones or crew station data, earplugs must be used in conjunction with the inflight head gear.